

**SUBSURFACE INVESTIGATION FIELD ACTIVITIES REPORT
AND HUMAN HEALTH RISK ASSESSMENT
CHEVRON CINCINNATI FACILITY, HOOVEN, OH**

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1.0 EXECUTIVE SUMMARY

Chevron has conducted several investigations in Hooven since hydrocarbon was first identified on the groundwater beneath the town in 1996. These investigations culminated in submittal of a human health risk assessment (HHRA) in May 2000 (E&E, 2000), which was approved by the U.S. Environmental Protection Agency Region V (EPA). The HHRA contained an evaluation (in Appendix D of the HHRA) which determined that the vapor intrusion pathway was incomplete. The current investigation was conducted to reevaluate the vapor intrusion pathway in response to a request by the EPA, Region V, in correspondence dated January 7, 2004. EPA attributed the additional review and request to updates in toxicity data for benzene and ethylbenzene and to heightened concerns surrounding vapor intrusion issues. Additionally, there is a RCRA requirement to complete an Environmental Indicator determination under CA725.

During March – May 2005, Chevron conducted a comprehensive investigation of the potential for migration of vapors from the Light Non Aqueous Phase Liquid (LNAPL)/dissolved contaminant plume to indoor air. One focus of the sampling effort was to characterize the vapor source area, and the potential migration pathway from the impacted groundwater/LNAPL (approximately 55 feet below ground surface [ft-bgs]). This effort included collection of samples of LNAPL, groundwater, and vertically nested vapor samples. The vertically nested vapor samples were collected both inside and outside the areas of the LNAPL/dissolved contaminant plume.

Individual constituents commonly found in gasoline that were identified in the LNAPL are also found in the associated dissolved contaminant plume and in deep soil vapor samples collected from immediately above the water table, 55-60 ft-bgs. Concentrations of these constituents attenuate rapidly with distance above the groundwater table as illustrated in the Site Conceptual Model (Figure ES-1). None of the constituents commonly found in gasoline were detected in soil-gas at concentrations exceeding semi-site specific screening levels provided in the OSWER Draft VI Guidance (EPA, 2002b) at depths between 20 and 60 ft-bgs in any of the five nested vapor probes located within the footprint of the LNAPL or dissolved contaminant plume. Soil vapors are attenuated within a short distance above the groundwater table and do not reach ground surface. In accordance with the OSWER Draft VI Guidance and consistent with previous risk assessments conducted for the site, the vapor intrusion pathway is incomplete and vapors from the plume do not migrate to indoor air in residences in Hooven.

This conclusion is further supported by two additional lines of scientific evidence demonstrating that biodegradation is the dominant mechanism for attenuation of the petroleum hydrocarbon constituent concentrations in the deep vadose zone (~30-55 ft-bgs). The first line of evidence is that the rate of decrease in constituent concentrations above the

groundwater table is faster than that due to simple diffusion. The second line of evidence comes from soil-gas oxygen (O_2) and carbon dioxide (CO_2) concentration profiles collected above the LNAPL/dissolved contaminant plume. These profiles show decreasing O_2 and increasing CO_2 concentrations with depth indicating biodegradation activity. Mathematical modeling of vertical diffusion and biodegradation confirms the significant influence of biodegradation at this site. Collectively this evidence demonstrates that biodegradation is the dominant mechanism for attenuation of petroleum hydrocarbon constituent concentrations in the deep vadose zone within the plume footprint.

A second focus of the sampling effort was characterization of vapors in the shallow subsurface inside and outside of the plume area. A total of 75 sub-slab samples were collected inside (42 samples) and outside the plume area (33 samples). A total of 79 near-slab samples were collected inside (49 samples) and outside the plume area (30 samples). Samples were collected beneath homes with full concrete and combination concrete/dirt basements, and/or crawlspaces. Constituents commonly found in gasoline were detected in sub-slab and near-slab samples at similar low concentrations and at similar detection frequencies both inside and outside the plume. Sub-slab oxygen concentrations are also similar inside and outside the plume area. Sufficient oxygen is present to support active aerobic biodegradation. Volatile constituents that are not commonly associated with gasoline, and were not identified in the LNAPL or dissolved contaminant plume, were widely detected at low concentrations and at similar detection frequencies in the shallow samples both inside and outside the plume area as illustrated by the orange shading in Figure ES-1. In addition, methyl-tert-butyl-ether (MTBE), a gasoline additive that was not commonly used until after the Chevron refinery was shut down, was detected in some shallow soil-gas samples close to residences, but was not detected in any of the deep soil-gas samples collected directly over the plume. The shallow subsurface detections of common gasoline and other constituents are not associated with the plume at depth. Outdoor air samples collected during the project indicate that many volatiles, including constituents commonly found in gasoline, were frequently detected both inside and outside the plume area. Published studies and guidance documents (e.g. NJDEP, 2002; NYDOH, 2005; CA DTSC, 2005) state that many VOCs listed in the OSWER Draft VI Guidance are common at low levels in outdoor and indoor air, even in places away from groundwater or soil contamination. Because buildings exchange air with both the shallow soil gas around their foundations and the outdoors, it is reasonable to expect similar VOC concentrations in the shallow soil gas. In this study, soil gas samples were collected immediately proximal to home foundations (below or beside them) and as expected, VOC concentrations detected in the sub-slab and near-slab samples beneath Hooven homes and the atmospheric air samples collected around Hooven are consistent with the referenced studies. Therefore, with no complete pathway from Chevron's plume to the surface, the shallow soil vapors detected are attributed to background conditions related to human activities at the surface.

The initial step in conducting a risk assessment is determining whether a complete pathway exists from source to receptor. In this case the pathway considered is from the LNAPL/dissolved contaminant plume to indoor air. The results of this study support previous study results from Hooven that indicate that this pathway is not complete. Therefore the risk assessment for this pathway indicates that vapors from the contaminant plume do not present any measurable health risk to the residents of Hooven. Shallow soil vapors are attributed to surface activities and are not facility-related. Large studies of indoor air vapors at sites other than Hooven show that occurrence of low level background VOC concentrations are a common companion to human activity. Therefore, the primary conclusion of this study is that residents are not exposed to vapors originating from the plume that has migrated from the former refinery. Correspondingly, the results of this investigation demonstrate that the vapor intrusion pathway is incomplete and support a "YE" determination for the Environmental Indicator CA 725, i.e., human exposures are "under control" with respect to the vapor pathway in Hooven.

2.0 INTRODUCTION

This report, prepared jointly by Trihydro Corporation (Trihydro) and GeoSyntec Consultants, Inc. (GeoSyntec) for Chevron, presents the results of a subsurface investigation conducted in Hooven, Ohio during March-May 2005. The results of this investigation have been used to evaluate the potential for subsurface vapor intrusion to indoor air (the vapor intrusion pathway) in residences located in Hooven, Ohio from volatilization of petroleum hydrocarbons in groundwater or light, non-aqueous phase liquid (LNAPL) originating from the Chevron Cincinnati Facility (the "facility").

2.1 PURPOSE

Chevron has conducted several investigations in Hooven since hydrocarbon was first identified beneath the town in 1996. These investigations culminated in submittal of a human health risk assessment (HHRA) in May 2000 (E&E, 2000). The HHRA contained an evaluation (in Appendix D of the HHRA) which determined that the vapor intrusion pathway was incomplete. The current investigation was conducted to reevaluate the vapor intrusion pathway in response to a request by the United States Environmental Protection Agency (EPA), Region V, in correspondence dated January 7, 2004. On March 3, 2005, Chevron submitted a draft work plan ("the Work Plan") to the EPA detailing the proposed investigative procedures to sufficiently evaluate the vapor intrusion pathway (Trihydro and GeoSyntec, 2005). EPA verbally approved the Work Plan on March 31, 2005, and the final Work Plan incorporating EPA comments, was submitted on April 1, 2005. Field activities, in accordance with the Work Plan, were conducted between March and May 2005. As agreed during a meeting between Chevron and EPA on November 17, 2004, the approach outlined in the *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils*, dated November 2002 (EPA, 2002b), referred to as the OSWER Draft VI Guidance, was used as the basis for the evaluation, with consideration for changes that are to be incorporated in the revised Draft Guidance, scheduled for summer of 2005, as presented by EPA during the AEHS Vapor Intrusion Workshop in March 2005 (<http://iavi.rti.org/WorkshopsAndConferences.cfm>). This report's evaluation of the vapor intrusion pathway in Hooven also provides supporting documentation for a RCRA Corrective Action Environmental Indicator (EI; CA725) to be submitted June 30, 2005.

2.2 REPORT ORGANIZATION

The results of field activities, including discussions of procedures, field analyses, analytical results, and data analysis/interpretation are presented in this report in the following sections:

- Section 1.0 – Executive summary
- Section 2.0 – Provides a discussion of the investigation purpose and report organization
- Section 3.0 – Contains background facility information, including facility history, setting, and previous investigations
- Section 4.0 – Outlines the principal investigation objectives, scope of activities, and rationale for activities performed
- Section 5.0 – Details the methodology employed for data collection, including a discussion of access agreements, building survey and occupant questionnaires, subsurface soil-gas sampling activities, groundwater monitoring activities, and outdoor air monitoring
- Section 6.0 – Presents the results—by way of tables, figures, and discussion—of groundwater sampling, soil-gas monitoring, and outdoor air monitoring, in addition to building surveys and LNAPL analyses
- Section 7.0 – Presents a site conceptual model, including a discussion of the nature and extent of facility-related chemicals, an evaluation of subsurface pathways, potential receptors, background concentrations and sources, and areas of uncertainty
- Section 8.0 – Provides a pathway analysis and interpretation
- Section 9.0 – Summarizes study conclusions and recommendations
- Section 10.0 – References
- Section 11.0 – Appendices

3.0 BACKGROUND

This section provides detail on the facility history, including a discussion of the regulatory history of the vapor intrusion pathway. Additionally, a summary of previous investigations that have been conducted as part of the vapor intrusion pathway analysis is included below.

3.1 SITE HISTORY AND SETTING

The Chevron Cincinnati Facility was a fuel and asphalt petroleum refinery located approximately 20 miles west of Cincinnati, Ohio, near the intersection of State Route 128 and United States Highway 50 (Figure 1). The facility operated from 1931 to 1986. During this time, refinery operations resulted in impacts by certain petroleum and petroleum-related constituents to groundwater and soil beneath the former facility. The majority of the facility has been dismantled since the refinery ceased production in 1986.

In 1985, an oily sheen was observed on the water of the Great Miami River along the southeast portion of the facility. Hydraulic containment measures were instituted that year to minimize migration of petroleum hydrocarbons off-site. On May 13, 1993, Chevron U.S.A. Inc. (Chevron) entered into an Administrative Order on Consent (Consent Order) with the EPA. One of the Consent Order requirements stipulated that Chevron perform a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) under Section 3008(h) of RCRA. During the RFI, a subsurface investigation was performed to characterize the nature and extent of dissolved phase and LNAPL impacts to soil and groundwater beneath the former facility. Chevron's investigation determined that there were impacts to groundwater that extended off-site to the west and southwest, including groundwater located beneath a portion of the unincorporated town of Hooven, Ohio, located across State Route 128 from the southern portion of the former facility (Figure 2a). Hooven consists of a mixed commercial/residential area and a public elementary school.

Chevron submitted a document to the EPA entitled *Human Health Risk Assessment (HHRA) of Potential Exposure to Volatile Compounds, Hooven, Ohio* dated May 2000, prepared by Ecology and the Environment (E&E, 2000). The HHRA included mathematical modeling of subsurface vapor intrusion into buildings in Hooven, which was prepared based on industry standards at the time, using default construction types typically included in an indoor air evaluation, including full basement with concrete slab and slab-on-grade scenarios. The EPA approved the HHRA in 2000.

More recently, the EPA submitted a letter to Chevron on January 7, 2004, in which EPA summarized its review of the Hooven 2000 HHRA. EPA attributed the additional review to updates to toxicity data for benzene and ethylbenzene and to heightened concerns surrounding vapor intrusion issues. As a result of these concerns, the EPA requested that Chevron revisit the HHRA with two specific tasks in mind. The first task was to update the evaluation with the newest toxicity data available. The second task was to reevaluate the crack ratio assumptions used in the mathematical model of subsurface vapor intrusion employed in the HHRA. In response to these concerns, Chevron conducted door-to-door home surveys, primarily focused on homes located over the LNAPL/dissolved contaminant plume. The results of this survey indicated that there are two basic home construction types in Hooven, Ohio consisting of:

- full basements with concrete floors; and
- basements with combination concrete/dirt floors and/or dirt crawlspaces.

Due to the findings of the home surveys, increased understanding of the vapor intrusion pathway in the scientific community and the development of new guidance for evaluating the vapor intrusion pathway (i.e., EPA, 2002b), Chevron volunteered to collect additional data to evaluate the vapor intrusion pathway.

3.2 REGULATORY FRAMEWORK

Since Ohio does not have State-specific guidance for assessing vapor intrusion the OSWER Draft VI Guidance was followed, with consideration given for planned revisions to this guidance in 2005, as presented by the EPA in the Vapor Intrusion Workshop of the American Environmental Health Sciences Conference in March, 2005. In the OSWER Draft VI Guidance, the EPA recommends a tiered approach to evaluating vapor intrusion into indoor air. This tiered approach involves the following steps in determining the presence/absence of vapor intrusion:

- Tier 1
 1. Determine if volatile/toxic chemicals are present
 2. Determine if inhabited buildings are, or could potentially be, located near subsurface contaminants
 3. Determine if potential risks warrant immediate action
- Tier 2
 1. Determine if measured indoor air, soil-gas or groundwater concentrations exceed screening levels in Table 2b (1.E-5 incremental cancer risk) of the OSWER Draft VI Guidance. For this study soil-gas samples from the

source and interval immediately above the source were screened against the screening values provided in Table 2b of the OSWER Draft VI Guidance assuming a generic attenuation factor of 0.01.

2. Determine if indoor air concentrations modeled from soil vapor or groundwater data exceed screening levels in the OSWER Draft VI Guidance using a semi site-specific attenuation factor developed using the Johnson and Ettinger (1991) model and information regarding the source depth and soil type for a specific site, which are provided in Figure 3a and Table 3b-SG of the OSWER Draft VI Guidance. For this study soil-gas samples from the source and interval immediately above the source were also screened against the screening values provided in Table 3b-SG of the OSWER Draft VI Guidance using attenuation factors derived from Figure 3a of the same document. This was completed in addition to the evaluation in step 4 above.

▪ Tier 3

1. Determine if indoor air concentrations either modeled from sub-slab samples or evaluated directly from indoor air samples exceed screening levels in the OSWER Draft VI Guidance (EPA, 2002b).

The OSWER Draft VI Guidance allows additional site-specific assessment supported by sampling activities and mathematical modeling. For the Hooven study area there are two key aspects of the subsurface fate and transport of petroleum hydrocarbon vapors that merit further assessment: intrinsic biodegradation and background sources. Vertical profiling of O₂, CO₂, and petroleum hydrocarbon vapor concentrations are essential to understanding intrinsic biodegradation (e.g., Roggemans et. al., 2001). Therefore, O₂, CO₂ and petroleum hydrocarbon vapor data were collected as a component of this investigation. These data are used in conjunction with mathematical modeling using the Dominant Layer Model ("DLM") to determine whether there is a complete pathway for vapors to migrate from the LNAPL and dissolved contaminant plume to indoor air.

The OSWER Draft VI guidance also clearly identifies that consideration of background sources is a key component of vapor intrusion evaluations. Hydrocarbon compounds may be present from a wide variety of different consumer products, including, but not limited to fuel oil, automotive products, small power tools, oil used to control dust on former gravel roads in Hooven, tobacco smoke, combustion of wood, coal or candles, and ambient outdoor air. It can be difficult to collect representative samples of all possible sources of vapors. However, the scope of work was designed to provide an appropriate amount of data for distinguishing background sources. Background indoor and ambient data were included in the OSWER Draft VI Guidance, and since its publication, the results of additional studies have become available (NYDOH, 2005). These data are considered in the site-specific assessment of the potential for vapor intrusion.

3.3 PREVIOUS INVESTIGATIONS

Previous investigations conducted at the facility and in Hooven are summarized below. Investigation results have been documented in previous reports, as cited below.

3.3.1 PHASE I RFI (1996)

On May 13, 1993, Chevron entered into an Administrative Order on Consent (Consent Order) with EPA Region 5 to perform a RFI under 3008(h) of RCRA at the Chevron facility in Hooven, Ohio. In accordance with the Consent Order and work plan schedule, Chevron commenced field investigations in March 1996.

In accordance with the RFI work plan, Phase I of the RFI focused, in part, on evaluating the groundwater conditions at and near the perimeter of the Chevron facility. If impacts were detected at the facility perimeter, Chevron had committed to EPA that it would expand the investigation to determine the extent of the contamination.

Three groundwater monitoring wells (MW-81S, MW-81I, and MW-81D) were installed in March 1996 (Figure 2a). Sampling of the 81 series wells indicated that light non-aqueous phase liquid (LNAPL) had migrated beyond the western perimeter of the Chevron facility. Additional wells (MW-92S, MW-92D, MW-93S, and MW-93D) were subsequently installed in the Hooven area in December 1996 to further evaluate the extent of LNAPL migration. The 92 and 93 series wells were sampled during March 1997 as part of the Phase I RFI sampling. LNAPL was detected in samples collected from the 92 and 93 series wells and the wells were subsequently resampled during June 1997 to confirm the March 1997 sampling event results.

Additional monitoring wells, MW-94S and MW-94D, were installed in July 1997 and monitoring wells MW-95S, MW-95D, MW-96S, MW-96D, and MW-97D were installed in August 1997. LNAPL was detected in monitoring wells MW-96S and MW-96D. As a result, monitoring wells MW-99S, MW-100S, and MW-101S were installed in October and November 1997 to further evaluate the extent of impacts in Hooven.

3.3.2 HOOVEN GROUNDWATER INTERIM MEASURES (1998)

Following completion of the Phase I RFI and EPA approval of the Phase I Technical Memorandum, Chevron received approval from EPA to revise the ongoing Interim Measures (IM). This revision included addition of wells in the Hooven area to the dissolved phase groundwater monitoring program.

As a result of the Phase I RFI LNAPL discovery in Hooven, Chevron expanded the investigation. Revisions to the monitoring program included incorporating the RFI Phase I perimeter groundwater monitoring wells and the Hooven area groundwater monitoring wells into the IM program (MW-81S, MW-81D, MW-85S, MW-85D, MW-93S, MW-93D, MW-94S, MW-95S, MW-95D, MW-99, MW-100, and MW-101).

3.3.3 INITIAL VAPOR SAMPLING ACTIVITIES (1997)

Vapor sampling was not specified in the RFI work plan; however, vapor sampling activities were performed by Chevron to obtain additional information about the potential extent of contamination. In order to evaluate the presence and extent of petroleum hydrocarbon vapors in the unsaturated zone above groundwater (vadose zone) in the vicinity of Hooven, soil borings VB-81, VB-92, and VB-93 were installed in June 1997. Vapor samples were also collected at 10 foot intervals from the hollow stem augers borings during the drilling and installation of monitoring wells MW-94S, MW-95S, and MW-96S in July and August 1997.

3.3.4 ADDITIONAL VAPOR MONITORING WELL INSTALLATION (1997)

To further evaluate the presence and extent of petroleum hydrocarbon vapors in the vadose zone beneath the Hooven area and to evaluate potential seasonal influences on vapor migration, three vapor monitoring wells (VW-93, VW-96, and VW-99) were installed in Hooven at locations above the LNAPL plume. Vapor monitoring wells VW-93 and VW-96 were installed in July and August 1997. Vapor monitoring well VW-99 was installed in November 1997. Eleven separate vapor monitoring points were installed in each vapor well nest. The vapor monitoring points were set at approximate 5-foot depth intervals between the depths of 10 and 60 feet below ground surface (ft-bgs).

Vapor samples were collected from each of the screened intervals from vapor monitoring well VW-93 in August 1997, VW-96 in September 1997, and VW-93, VW-96, and VW-99 in December 1997.

The vapor monitoring wells (VW-93, VW-96, and VW-99) were resampled once during low groundwater table conditions in December 1998 and once during high groundwater table conditions in February 1999. The purpose of the resampling events was to evaluate seasonal fluctuations in vapor concentrations and to verify previously collected data. The February 1999 groundwater elevations were approximately 6 feet higher than the December 1998 groundwater elevations. Greater than a foot of LNAPL was observed in each of the three wells during the December 1998 event. LNAPL was not observed during the February 1999 event. Vapor concentrations were generally higher during the February 1999 event compared to the December 1998 event (ESE, 1999).

The vapor data collected from wells VW-93, VW-96, and VW-99 were used to evaluate aerobic biodegradation effects on attenuation of vapors emanating from the LNAPL/dissolved contaminant plume. This evaluation was completed by Dr. Paul C. Johnson and was included as an Appendix of the *Human Health Risk Assessment of Potential Exposure to Volatile Compounds* (E&E, 2000). Vapor concentrations were predicted using a vapor transport model with an oxygen-limited first-order kinetics component. The model predicted the concentration of total petroleum hydrocarbon vapor at differing depths from the source based on the rate of biodegradation using hydrocarbon/oxygen ratios, distance from the source and concentration at the source. This evaluation provided evidence for an incomplete vapor pathway. This modeling was used to develop the site conceptual model presented in the *Conceptual Groundwater Remedy Report for the Chevron Texaco Cincinnati Facility* (CT Cincinnati GW Task Force, 2003). The current investigation was designed to test the vapor site conceptual model through re-sampling of the nested wells VW-93, VW-96 and VW-99, installation of additional nested vapor monitoring wells VW-127, VW-128, VW-129 and VW-130, and additional mathematical modeling.

3.3.5 HORIZONTAL SVE SYSTEM INSTALLATION AND OPERATIONAL HISTORY

As a proactive and voluntary measure, Chevron installed a horizontal soil vapor extraction (HSVE) system beneath portions of Hooven to remove and prevent the upward migration of petroleum hydrocarbon vapors identified in the deep vadose zone during the vapor sampling that was completed from 1997 through 1999. The HSVE system includes three horizontal vapor extraction wells, installed between 1999 and 2000 which extend approximately 800 feet from the Chevron property westward beneath Brotherhood Avenue, Hooven Avenue, and Ohio Street in Hooven. The horizontal vapor recovery wells were designed to remove soil vapors directly above the groundwater table surface and were screened to provide a 5-foot buffer above the previously observed 15-year maximum seasonal water table elevation. Extracted vapors were treated by combustion, with natural gas added as needed to maintain combustion.

The system commenced operation in November 1999 with only HSVE Well #1 online. The installation of the two remaining HSVE system wells (HSVE Well #2 and HSVE Well #3) was completed in 2000. These wells were brought online during the first quarter of 2001. During times of high groundwater table, petroleum hydrocarbon vapor removal decreased dramatically and it was determined that the system would be turned off due to low VOC recovery and the high rate of natural gas usage required to operate the HSVE system. The system extracts a combined flow rate of about 1,400 standard cubic feet per minute, when the petroleum hydrocarbon smear zone is exposed during low groundwater-table conditions.

Approximately 475,000 pounds of petroleum hydrocarbons have been removed by the horizontal vapor recovery wells to date. The rate of petroleum hydrocarbon recovery has decreased since commencement of the system in November 1999 and present. Approximately 270,000 pounds of petroleum hydrocarbons were removed between the commencement of the system (November 1999) and approximately one year later when HSVE wells #2 and #3 were added to the system. During the subsequent year (2001), approximately 163,000 additional pounds of petroleum hydrocarbons were removed. Approximately 42,000 additional pounds of petroleum hydrocarbons were removed during 2002. No substantial incremental petroleum hydrocarbon mass removal occurred during 2003 to date. The system was operated minimally from November 3 until December 16 during 2004 and has since remained off since due to high groundwater table conditions.

3.3.6 VAPOR FLUX TESTING (1998)

Chevron voluntarily conducted vapor flux testing in August 1998 to further evaluate the rate of emissions (if any) from the LNAPL/dissolved contaminant plume underlying portions of Hooven.

Surface vapor flux testing was conducted at 23 locations in the Hooven area. These testing location included locations along State Route 128, at locations in Hooven both inside and outside of the dissolved contaminant plume, the elementary school property, and at background locations.

Surface flux sampling was conducted using a flux chamber comprised of an acrylic-topped, stainless steel cylinder. The flux chamber was placed on the ground surface and "sweep air" (dry, hydrocarbon-free air from compressed gas cylinders) was added to the flux chamber at a flow rate of five liters per minute. The outlet gas concentration was monitored using organic vapor meters to determine when steady state concentrations were achieved. When steady state organic vapor concentrations were reached, samples were collected in 6-Liter Summa canisters.

Downhole vapor flux testing was conducted at three locations over the LNAPL/dissolved contaminant plume in Hooven in soils borings DVF-1, DVF-2, and DVF-3. Samples were collected from depths of 5, 10, 20, 40, and 60 ft-bgs in borings installed using vapor flux chambers comprised of an acrylic cylinder installed temporarily using hollow stem auger techniques. The augers were advanced to the designated depth interval and the downhole flux chamber was lowered to the bottom of the augers. "Sweep air" was then added and the outlet gas concentrations were monitored using organic vapor meters. When steady state organic vapor concentrations were reached, gas samples were collected using 6-Liter Summa canisters.

Results of the vapor flux sampling event are summarized in the *Hydrocarbon Vapor Assessment Report for the Hooven, Ohio Area* (Appendix G of ESE, 1999).

3.3.7 HOOVEN HUMAN HEALTH RISK ASSESSMENT (2000)

The surface and downhole flux data collected in 1998 were used to prepare the *Human Health Risk Assessment of Potential Exposure to Volatile Compounds* (2000 HHRA) dated May 2000 (E&E, 2000).

The surface flux data was used to evaluate four slab-on-grade construction scenarios. All four of the scenarios took into account exposure to both indoor and outdoor air. These four scenarios can be summarized as follows:

- Boundary – The boundary scenario was a residential scenario and included the nine surface flux samples that were collected at the Chevron property line (on or near State Route 128)
- Hooven Composite – Hooven composite was a residential scenario and included all 23 surface flux samples collected as part of the HHRA investigation.
- School Student – scenario to evaluate the risk to students at the elementary school and included the five surface flux samples collected on school property.
- School Faculty and Staff – scenario to evaluate the risk to the adult workers at the elementary school and included the five surface flux samples collected on school property.

The downhole flux data was used to conduct an evaluation of the Hooven basement scenario. This evaluation was based on the three downhole vapor flux samples collected at the 10 ft-bgs interval.

The 2000 HHRA concluded that the residential cancer risks and non-cancer hazards were acceptable and within EPA's target excess cancer risk range of $1.E-6$ and $1.E-4$ and within mathematical error of the target hazard index of 1. Appendix D of the 2000 HHRA report presented an evaluation of data from the vapor nests which provided evidence that the vapor migration pathway was incomplete. The current investigation serves as a test of that evaluation.

The data used in the 2000 HHRA were collected in the shallow surface soils in the upper 10 feet of the soil column, and no effort was made to subtract or distinguish the contributions from background sources. Therefore, these results would be expected to overestimate risks attributable to facility-related petroleum hydrocarbons.

3.3.8 SEWER LINE INVESTIGATION (2004)

In cooperation with the Whitewater Township Regional Sewer District (WTRSD) Chevron conducted an investigation to assess any risk that may be posed to construction workers during installation of sanitary sewer lines in Hooven (Trihydro, 2004a). Completed in July 2004, the investigation included shallow soil vapor monitoring and soil sampling inside and outside of the LNAPL/dissolved contaminant plume. The risk assessment findings indicated that the potential risk associated with exposure to soil and vapor during installation of the sanitary sewer in Hooven are below the EPA thresholds for both cancer and non-cancer risk. However, the study did identify some detectable, but low concentrations of vapor and soil contaminants, both inside and outside of the plume. These were “possibly attributable” to human activities at the surface. As indicated in Section 8, the results of the sewer line investigation are consistent with the results of the current study.

4.0 OBJECTIVES, SCOPE AND RATIONALE

In this section, study objectives are discussed in terms of conditions encountered in the field. Changes in the scope due to field or other conditions are also addressed.

4.1 STUDY OBJECTIVES

As presented in the Work Plan (Trihydro and GeoSyntec, 2005), the primary objectives for this evaluation were as follows:

1. Determine if a human health risk is potentially present in the indoor air of Hooven homes as a result of vapor transport from the LNAPL/dissolved contaminant plume originating from the former Chevron refinery and located under a portion of Hooven; and
2. Assess whether petroleum hydrocarbon constituents (if present) in shallow soil vapors or indoor air are attributable to the subsurface LNAPL/dissolved contaminant plume from the former refinery in the groundwater or to other background or ambient sources.

4.2 SCOPE AND RATIONALE

The scope of investigation was designed to satisfy the requirements of the OSWER Draft VI Guidance and anticipated revisions expected in 2005, and provide sufficient information for an Environmental Indicator determination of the vapor intrusion pathway. Specifically, Chevron performed the following:

1. A building survey and occupant questionnaire was conducted at accessible homes in Hooven, based on the form provided in Appendix H of the OSWER Draft VI Guidance in order to communicate with the community, gather relevant information about building design and condition, and identify and attempt to isolate potential interior sources of vapors. The "occupied dwelling questionnaires", presented in Appendix A, were used to identify home construction types and lifestyle factors that may affect sample collection and results. For the two basement types (full concrete basement and combined concrete/dirt basement and/or dirt crawlspace), the study was designed to sample approximately equal numbers of each inside and outside the LNAPL/dissolved contaminant plume. Samples were collected for shallow soil-gas (sub-slab and near-slab) from residences where signed access agreements were obtained except in cases where sufficient samples had already been collected for a particular construction type and location or an access agreement was executed for another purpose such as installing groundwater or deep nested vapor monitoring wells.

2. Sub-slab vapor monitoring probes were installed through the floor slabs of 43 structures (including the Hooven Elementary School) (Figure 2b) in Hooven (approximately half overlying the known distribution of petroleum hydrocarbons from the former refinery and half in the region beyond the dissolved contaminant plume). Two dozen more sub-slab samples were collected than originally scoped for in the Hooven Vapor Investigation Sampling and Analysis Work Plan (TriHydro and GeoSyntec, 2005), where access was granted by local residents, and this supplemental sampling provides additional assurance in the results and conclusions of the study. The sub-slab vapor samples from each probe were submitted for laboratory analysis of concentrations of target chemicals, in accordance with the OSWER Draft VI Guidance. Sub-slab probes were also monitored for O₂ and CO₂ to assist in evaluating biodegradation and pneumatic tests were performed to assess the sub-slab gas permeability. The sub-slab sampling locations were selected following completion of detailed home surveys and execution of access agreements from property owners.
3. Two shallow soil-gas probes were installed as close as practicable beside the foundation ("near-slab" samples) of each of the structures where sub-slab samples were collected (Figure 2b). The near-slab probes were sampled for soil-gas at a depth of 5 ft-bgs to correspond with the bottom of the floor slab, and a depth approximately 10 ft-bgs, with pneumatic testing, screening by landfill gas meter, and laboratory analysis of concentrations of target chemicals, in order to assess the correlation between the sub-slab and near-slab samples in terms of compounds detected, relative concentrations, O₂ and CO₂ concentrations, and soil-gas permeability. Additionally, at one location over the LNAPL/dissolved contaminant plume and one location outside of the LNAPL/dissolved contaminant plume, two soil-gas probes were installed at the depths described above on all four sides of the building to evaluate potential environmental effects on shallow vapor concentrations (i.e., wind, temperature, exposure to sun).
4. Four new deep nested vapor monitoring wells were installed in locations both over (VW-127 and VW-128) and outside (VW-129 and VW-130) of the dissolved contaminant plume (Figure 2a). Soil vapor samples were collected from the four new deep nested wells at all screened intervals, summarized in Table 1, together with three existing nested soil vapor monitoring wells (VW-93, VW-96, and VW-99) located over the LNAPL/dissolved contaminant plume. Vapor wells HVW3 and HVW9 were originally scoped to be sampled as part of the work. However, HVW3 was not sampled because a new nested vapor well (VW-128) was installed near HVW3 at deeper depths. During the sewer line investigation, samples were collected from HVW9, located outside the LNAPL/dissolved contaminant plume and adjacent to the fire station (Trihydro, 2004a). Concentrations were detected in the shallow zone that appear to be related to a localized surface or shallow sub-surface release. The reported benzene concentration at the 10 ft-bgs sampling interval was the highest detected concentration of

benzene during the sewer line investigation ($53 \mu\text{g}/\text{m}^3$). Because of the suspected alternate source well HVW9 was not sampled. The deep nested vapor monitoring results serve to characterize intrinsic biodegradation within the unsaturated zone and to better understand the subsurface distribution of background vapors from other sources.

5. Nine groundwater monitoring wells (Figure 2b) were installed and sampled to better define the extent of the LNAPL and dissolved contaminant plume in Hooven.
6. Three outdoor ambient air samples were collected using 6-L Summa canisters with 8-hour flow controllers for analysis of VOCs by Method TO-15 on each day during which soil vapor samples were collected (Figure 2b). The ambient air samples were submitted for laboratory analysis to characterize ambient air quality and assist with understanding the potential contribution of vapors from ambient (outdoor) air.
7. Soil samples were collected and analyzed for geotechnical properties to provide site specific data to be used as modeling inputs, if needed.

Deep soil vapor concentrations were compared to the screening levels provided in Table 2b of the OSWER Draft VI Guidance, incorporating a generic attenuation factor of 0.01. Deep soil vapor concentrations were also compared to screening levels using semi-site specific attenuation factors from Figure 3a and Table 3b-SG, which range from $1.E-3$ to $7.E-4$. It is important to emphasize that these attenuation factors do not account for biodegradation, which is clearly occurring at the site, and therefore; the Table 3b-SG screening levels are very conservative. Concentrations of VOCs in sub-slab samples were compared to near-slab samples and background to assess whether the constituents present in the sample set were attributable to the LNAPL/dissolved contaminant plume and to evaluate any spatial trends. This evaluation is presented in Section 8.6.

The data collected from the deep nested wells was used in unison with the LNAPL/dissolved contaminant plume data and the O_2 and CO_2 data to evaluate the soil vapor profiles in the deep soil-gas. This evaluation is presented in Section 8.4. Based on the soil vapor profiles, the mathematical modeling of biodegradation rates and attenuation factors is provided in Section 8.5.

5.0 STUDY METHODS

The study methods were described in the Work Plan. This section provides greater detail on the methods used and describes any deviations from the Work Plan, executed in response to conditions encountered in the field.

5.1 ACCESS AGREEMENTS, BUILDING SURVEY AND OCCUPANT QUESTIONNAIRE

Prior to conducting any activities associated with the subsurface investigation, Chevron obtained access agreements with affected property owners and renters, the Southwest School District, and Whitewater Township. Chevron attempted to obtain access agreements with all property owners/renters of suitable building construction type located within the area of investigation (east of Jackson Street and west of Highway 128). The investigation focused, in part, on sampling beneath structures with basements because above ground living space typically has a higher air exchange rate with outdoor air compared to basements. Therefore, slab-on-grade and trailer style construction are considered less susceptible to vapor intrusion. Accordingly, access agreements with property owners/renters of trailer homes and buildings containing slab-on-grade foundations were not pursued. In some cases, Chevron was not able to contact a property owner after reasonable and considerable efforts (e.g., multiple contacts in person or by phone were attempted, but the homeowner did not respond). A portion of property owners elected not to sign access agreements. In these instances, Chevron did not encroach upon these properties.

For each property for which an access agreement was acquired, a building survey/occupant questionnaire, titled "The Hooven Occupied Dwelling Questionnaire/Indoor Air Assessment Survey", was completed with the property owner(s) and renter(s) (if any). Comprised of approximately 50 questions, the questionnaire served to characterize building design and condition, and to catalogue consumer products and building materials that might contribute to indoor air and/or secondary sources of VOCs. A total of 48 dwelling questionnaires were acquired representing 43 unique structures including the Hooven Elementary School. Copies of all completed questionnaires appear in Appendix A.

5.2 SOURCE CHARACTERIZATION

The first step in evaluating completeness of the vapor intrusion pathway is to determine what chemicals are present in the source that may migrate to indoor air. Source characterization tasks included collection and analysis of vapor samples from the source zone (immediately above the LNAPL), LNAPL samples and groundwater samples. Groundwater characterization procedures are described in Section 5.5. Deep vapor and LNAPL characterization are described below.

5.2.1 VAPOR PHASE CHARACTERIZATION

Vapor phase characterization of VOCs and SVOCs was conducted on the existing nested vapor wells over the plume (VW-93, VW-96, VW-99) using soil vapor probes immediately above the water table. Volatile Organic Sampling Train (VOST) tubes were filled with XAD resin by Air Toxics Laboratories (ATL) of Folsom, California. Two VOST tubes were connected in series via compression fittings to the probe and approximately 180 to 294 L of soil vapor was drawn through the sampling train at a rate of approximately 5 L/min by the use of a vacuum pump. One outdoor air sample was also collected. All tubes, including duplicates were shipped to ATL under chain of custody and analyzed by modified method TO-13A including tentatively identified compounds (TICs) via solvent extraction followed by GC/MS.

5.2.2 LNAPL CHARACTERIZATION

LNAPL samples were collected from monitoring wells MW-96S and MW-99S during execution of the Hooven Vapor Investigation to more fully characterize the constituents and relative concentrations present in the LNAPL plume that extends beneath a portion of Hooven. LNAPL samples were collected using 1.75-inch single check disposable polyethylene bailers.

The lids on each sample container were tightly secured and the sample label filled out completely including sample identification, date and time of collection, project name, client name, field personnel initials, requested analyses, and preservation methods. The sample containers were placed on ice and proper custody maintained. Glass containers were protected against breakage during transport to the laboratory.

LNAPL samples were submitted for analysis of volatile organic constituents (VOCs) via EPA Method 8260B and SVOCs via EPA Method 8270C. LNAPL samples were submitted to Energy Laboratories located in Billings, Montana. Proper sample custody was maintained during completion of LNAPL collection. A chain-of-custody form, temperature blank, and trip blank were submitted with each sample cooler shipped to the laboratory.

5.3 INSTALLATION OF SOIL VAPOR PROBES/MONITORING WELLS

A general description of soil vapor probe and monitoring well installation procedures was provided in the Work Plan. Additional details are provided below.

5.3.1 SUB-SLAB VAPOR PROBE INSTALLATION

Residences were selected for sub-slab sampling to evaluate whether there might be statistically significant differences between construction types (full basement vs. crawlspace) and between locations relative to the extent of the LNAPL/dissolved contaminant plume (inside vs. outside). Sub-slab probes were installed at 21 separate structures (eight full basement and 13 partial basement) in locations near or over the LNAPL/dissolved contaminant plume and 22 separate structures (12 full basement and 10 partial basement) in locations outside of the LNAPL/dissolved contaminant plume (Table 2). Two sub-slab probes were installed and sampled in each of the 43 locations, with the following exceptions. Only one sub-slab probe was installed at locations identified as CHI9, HOO10, HOO17, HOO18 and OHI4 due to the small area of the partial concrete pad within the basement. In addition, only one sub-slab probe was installed at the location identified as HOO14 because water was observed flowing up through the hole drilled in the second sampling location. Four sub-slab probes were installed at the location identified as CHI8 to assess whether the additional probes provided insight into spatial variability of subsurface vapor concentrations. The sub-slab sampling locations are shown on Figure 2b.

The collection of samples from HOO7-SS1/SS2, HOO10-SS1/SS2, HOO13-SS1/SS2, and HOO14-SS1/SS2 was not possible due to water encountered beneath the slab during sampling.

5.3.1.1 PROBE DESIGN AND CONSTRUCTION

Prior to probe construction, the locations of underground utilities were assessed and probe locations were selected to avoid them. Locations were selected to be 5 feet away from the edge of the floor slab or wall to the extent practicable. The sub-slab probes consisted of a 1/4-inch (nominal) diameter brass pipe approximately 4-inches in length, with a compression-fit coupling to a female NPT thread at the top. A stainless steel ball valve with a 1/4-inch compression fitting was attached to the top of the probe. The sub-slab probes were installed by drilling a 5/8-inch diameter hole through the floor slab, reaming the upper 2-inches to a 1-inch diameter, clearing concrete dust, placing the probe into the hole and sealing the upper 2-inches with fast-setting, hydrating (swelling) cement. The seal generally set within 10 minutes. The seal integrity was verified using the helium tracer method, described in Section 5.4.3.

After sampling, the probes were removed. The holes were sealed with cement and smoothed with a trowel to a flush finish. All dust was removed with a small vacuum cleaner.

5.3.2 NESTED AND NEAR-SLAB VAPOR WELL SOIL BORING INSTALLATION

Prior to installation of the soil borings, Chevron obtained necessary permits from the Hamilton County Engineer's Office and access agreements from Whitewater Township and private property owners. Underground utilities were clearly identified via notification to Ohio Utilities Protection Service (OUPS) prior to installation of the nested soil vapor monitoring wells. A private utility locate service (Blood Hound Incorporate Subsurface Utility Engineering) was subcontracted to locate and mark underground utilities at each location prior to installation of the near-slab soil vapor monitoring wells. Soil borings were installed via direct push drilling technique utilizing an AMS 9630 Power Probe or Geoprobe® 540MT.

5.3.3 SOIL SAMPLING PROCEDURES

A 2.5-inch or 2.75-inch soil boring was cored using a 5-foot continuous core sampler to total depth at each proposed soil vapor monitoring well location. Soil samples were collected in accordance with the following procedures:

- Field team personnel wearing disposable nitrile gloves extracted the samples from the continuous sampler. Soil from the uppermost section of the sampler was discarded, as it may have contained borehole slough;
- An aliquot of the soil from each 5-foot interval was placed in a re-sealable plastic bag and the headspace was monitored for total organic vapors;
- Soil samples with visible staining or total organic vapor concentrations greater than 50 parts per million were collected for laboratory analysis;
- Soil samples targeted for geotechnical analysis were identified and the desired interval isolated; and
- The remaining soil from each borehole was used by the field geologist to produce a lithologic log in general accordance with ASTM standards. Additional information, such as odors, discoloration, artificial/non-native debris, and observations pertaining to potential petroleum hydrocarbon impacts were noted on the lithology logs. Lithology logs for each soil boring installed for completion as near-slab soil vapor monitoring wells are provided in Appendix B. Lithology logs for each for soil borings installed for completion as nested soil vapor monitoring wells are also provided in Appendix B.

5.3.4 ORGANIC VAPOR SCREENING

Soil samples were screened for total organic vapor using a Thermo Environmental 580EZ, Thermo Environmental 580S2, or MiniRae 2000 photoionization detector (PID). The PID was calibrated daily, in accordance with the

manufacturer's guidelines, to a factory-prepared 100 parts per million isobutylene standard. Each sample was allowed to equilibrate to room temperature before screening for total organic vapors. The total organic vapor measurement for each five foot interval was recorded on the lithology log (Appendix B) in parts per million, relative to the calibration standard. The accuracy of the PID was checked at the conclusion of each day by screening the PID against the 100 parts per million isobutylene standard.

5.3.5 SAMPLE COLLECTION FOR SOIL QUALITY ANALYSIS

Soil samples were collected from each borehole for laboratory analysis based on the field screening results and physical observations. The samples were collected and analyzed in general accordance with the Test Methods for Evaluating Solid Waste, EPA, SW-846 (SW-846, Revision 3, June 1997). Any soil samples with visible staining or total organic vapor concentrations greater than 50 parts per million were collected in a 12-ounce wide glass jar with no preservative and submitted for analysis of semivolatile organic constituents (SVOCs) via EPA Method 8270C.

The lids on each sample container were tightly secured and the sample label filled out completely including sample identification, sample interval, date and time of collection, project name, client name, field personnel initials, requested analyses, and preservation methods. The sample containers were placed on ice and proper custody maintained. Glass containers were protected against breakage during transport to the laboratory. A chain-of-custody form and temperature blank were submitted with each sample cooler shipped to the laboratory. The soil samples were submitted to Lancaster Laboratories, Inc. located in Lancaster, Pennsylvania.

5.3.6 SAMPLE COLLECTION FOR GEOTECHNICAL ANALYSES

Field team personnel extracted the samples within 5-foot acetate liners from the continuous sampler. Soil samples targeted for geotechnical analyses were isolated and remained intact. The acetate liner containing the desired soil interval was then cut and ends capped to prevent agitation during shipment. Samples that were collected solely for particle size distribution were collected in a 4-ounce wide mouth glass jar with no preservative. The sample identification, date and time of collection, and sample interval were clearly marked on the geotechnical sample.

Soil samples from selected borings were submitted for geotechnical analysis for Atterberg limits (ASA1 Method 31-1), bulk density (ASA1 Method 30-2), moisture content (ASTM Method D2216), total porosity (ASA1 Method 21-2.2), and/or particle size distribution (ASTM Method D422). Proper sample custody was maintained during collection and

shipment of the geotechnical samples. Glass containers were protected against breakage during transport to the laboratory. A chain-of-custody form accompanied the samples to the laboratory. Geotechnical samples were submitted to Colorado Analytical Laboratories, Inc. located in Brighton, Colorado.

5.3.7 DECONTAMINATION PROCEDURES

Before arriving at the site, the drill rig, tools, and accessories were thoroughly decontaminated with a pressure washer/steam cleaner. Down-hole equipment was decontaminated between borings at the Chevron Cincinnati Facility using a hot water pressure washer.

Soil sampling equipment was decontaminated between sample intervals using a phosphate-free detergent wash, and a potable water rinse followed by a distilled water rinse. Soil cuttings were containerized and transported to the Chevron Cincinnati Facility for appropriate handling and disposal. Decontamination fluids were collected and disposed of into the on-site wastewater treatment facility.

5.3.8 NEAR-SLAB SOIL VAPOR MONITORING WELL INSTALLATION

Near-slab soil-gas probes were installed adjacent to the basement/crawlspace of structures selected for sub-slab sampling to provide data to assess whether the near-slab probes would provide data comparable to the sub-slab probes. The near-slab probes were all installed in pairs, with one probe screened at or near the elevation of the sub-slab samples (i.e., typically about 5 ft-bgs) and the second probe screened deeper (typically 10 ft-bgs) to assess whether there was any discernable vertical profile in subsurface vapor concentrations. A total of 50 near-slab soil-gas probe clusters were installed: four at each of locations CH11 and MON2, two at location CH18, and one at the remaining 40 locations. The near-slab soil-gas probes were installed within the 2.5-inch or 2.75-inch soil boring installed via direct push drilling technique utilizing the AMS 9630 Power Probe or Geoprobe® 540MT. The near-slab sampling locations are approximately three feet from the building structure and are shown on Figure 2b.

5.3.8.1 PROBE DESIGN AND CONSTRUCTION

Near-slab soil-gas probes were constructed of ¼-inch diameter Nylaflo™ tubing attached with a compression fitting to a 6-inch length of 1-inch schedule factory slotted 40 PVC screen. The bottom of the PVC screen was completed with a 1-inch schedule 40 PVC slip cap. The top of the PVC screen was completed with a 1-inch schedule 40 PVC slip cap threaded with a ¼" compression fitting. The soil-gas probes in each cluster were placed in separate but adjacent boreholes typically less than 4 feet apart. Construction diagrams for each of the near-slab vapor wells installed in Hooven during the vapor investigation are provided in Appendix B.

5.3.8.2 SETTING FILTER PACK AND SEALS

Silica filter sand was placed around the screened interval to 6-inches above the top of the screen. A granular bentonite bridge was then placed above the filter-pack in two 3-inch lifts, which were individually hydrated with distilled water prior to placing the next lift. The remainder of the borehole annulus was filled by pouring a thick slurry of powdered bentonite and water to ground surface. All surface completions were 8-inch diameter, lockable casings. The northing and easting coordinates were surveyed relative to the state plane coordinate system utilizing a Trimble ProXRS Global Positioning System (GPS) unit. The horizontal accuracy for the near-slab soil vapor wells was established as +/- 3.0 feet. The well designation and screen interval for each of the near-slab soil vapor probes was clearly labeled within the flush-mounted vault. Vapor monitoring well completion logs are presented in Appendix B.

5.3.9 NESTED SOIL VAPOR MONITORING WELL INSTALLATION

Deep nested soil vapor monitoring wells were installed in four locations (VW-127, VW-128, VW-129, and VW-130) with designs similar to the existing nested soil vapor monitoring wells (VW-93, VW-96, VW-99). Well construction details are summarized in Appendix B. Nested soil vapor monitoring wells VW-127 and VW-128 were installed at locations over the LNAPL/dissolved contaminant plume, and nested soil vapor monitoring wells VW-129 and VW-130 were installed at locations outside (west) of the extent of the dissolved contaminant plume to provide data that can be used to compare and contrast the vertical movement of any petroleum hydrocarbon vapors in both areas. The nested soil vapor monitoring wells were installed in an 8-inch diameter borehole utilizing an Acker SoilMax hollow stem auger drilling rig. The boring was advanced from ground surface to approximately 50 ft-bgs. The nested soil vapor well locations are shown on Figure 2a.

Samples were not collected from the deep (60 ft-bgs) intervals of nested soil-gas probes VW-96 and VW-99 because the screen interval was below the groundwater table.

5.3.9.1 PROBE DESIGN AND CONSTRUCTION

The soil gas probes in nested soil vapor monitoring wells VW-127, VW-128, VW-129, and VW-130 were constructed of ¼ inch diameter Nylaflo™ tubing attached using a compression fitting to a 6-inch long, stainless steel GeoProbe® screen. The screened intervals were set at depths between 5 and 50 ft-bgs with vertical spacing of 5 or 10 feet (Table 1). A ¼-inch, stainless steel, compression fit ball valve was attached to the top of each probe. The ball valve for each probe was labeled with the associated well name and depth. Construction diagrams for each of the four newly installed nested soil vapor wells are provided in Appendix B.